**WHITE PAPER - BAA-N00173-03, 53-13-02 LOW COST WIDEBAND ANTENNA ARRAY**

**Area Being Addressed:** The team at the University of Malta aims to address the third area as it has expertise in designing low-profile, ultra-wide bandwidth (UWB) arrays which can be printed on a single layer such as the curved surface of a vehicle. The team is seeking funding to design an antenna element and system electronics, prototype and test such a system. Ideal/ Reference specifications for the antenna such as bandwidth, gain etc must be provided by the NRL. The team also strives to design low-cost solutions using PCB technology, aiming to reduce the cost of mass manufacture by at least a factor 5.

**Current Detection Capability:** The first application that led to the antenna design is the Square Kilometer Array (SKA)[1] Project, the world's largest radio telescope. No existing antenna meets the SKA's requirements, including stable pointing and accuracy in harsh desert environments, low-cost design for mass manufacture, reliability, feed flexibility and maximum sensitivity. The antenna array designed to meet these requirements is a passive prototype (Fig. 1) which has the following features and benefits:


Fig. 1

| Features of the SKA antenna design | Benefits |
|---|---|
| **Planar**, current design thickness is 2 mm | **Compact, Low Profile** and **Flexible**, allowing even curved structures |
| **Ultra-wideband** 10:1 (100 MHz – 2 GHz) | **Reduced Cost** as a result of **Multi-functionality** due to single wideband aperture |
| **Beamwidth (3dB),** 80° Azimuth and elevation | **Reduced Interference** |
| **Polarisation**, slant linear | **Wide Field of View** |
| **Fractal**<br>The octagonal elements made of triangular shapes, not rings, tuned to optimise UWB feature | **Improved Broadband Performance**<br>**Reduced Cost** due to 20% less metal than solid rings |
| **Size** of single-element UWB fractal octagonal ring antenna is <150 mm x <150 mm | **Ease of Manufacture** and **Scalable** |
| **Gain** of -10 dBi | **Low Cross-polarisation** Performance |
| **Lightweight Construction** | **Easy to Transport** |
| **Produced by PCB Manufacture**, can be printed on a single layer such as a thin substrate or the (curved) surface of vehicle | **Ease of Manufacture** and **Reduced Cost** |
| Voltage Standing-Wave Ratio (**VSWR**) < 2 | **More reliable** due to higher absorption by FSS |

A prototype of a 4 x 4 element of the proposed array was fabricated, measured and simulated to investigate its performance. It exhibits a wideband performance characterised by a reflection coefficient parameter below -10 dB above 90 MHz for the immersed centre element, see (Fig. 2). A low cost Near-Field to Far-Field antenna measurement system was used for the evaluation of far-field patterns of the array. A high level of agreement has been observed between measurements and simulations.

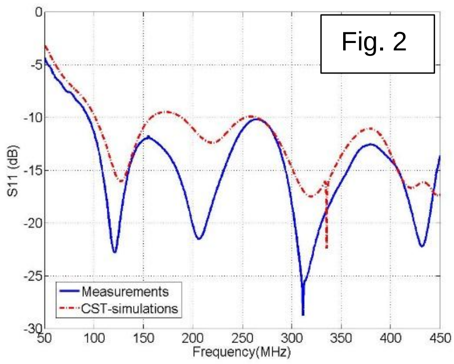

Fig. 2

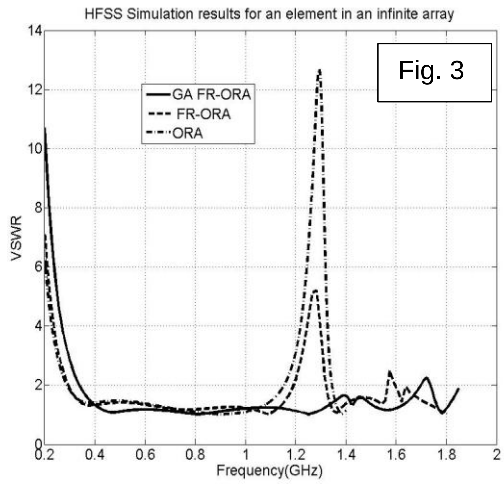

Fig. 3

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[1] https://www.skatelescope.org/

**Comparison of Proposed Approach with Conventional Techniques and Technology:** Due to the effect of radiation cancellation from ground plane image current, conventional arrays are short-circuited at the high-end of the operating band. To obtain an ultrawide bandwidth ratio, the antenna design is loaded with an array of resistive square rings. The resistive FSS's  represent a solution to dampen the impact of this disturbance. The effect on the array response is significant when compared to a regular array without FSS. Employing the loaded array extends the bandwidth of the array, enabling a ratio bandwidth performance of 10:1.

The design can be tailored to any specific application, frequency specification and required bandwidth. The antenna design is optimised using genetic algorithms (GA). Once designed, the performance of the antenna can be reasonably well predicted through CST and HFSS[2] simulation. Through use of GA optimisation an infinite optimal array with the desired specifications is auto-constructed *in silico*. The optimal design parameters are obtained by constraining its unit cell variables, involving inter-element spacing, the number of the iterations of the octagonal ring, the element spacing, the distance to the ground plane, the matching layer displacement, and the matching layer scaling factor. The objective of this tool is to reduce the VSWR of the array performance over the entire operating frequency band. The GA-generated arrays show a greatly improved response over the operating frequency when compared to results from conventional design methods. Figure 3 illustrates an array designed to operate in the band of 300 - 1.7 GHz using GA optimisation versus the standard methods designs. The GA model has a markedly improved behaviour over the band of interest (VSWR <2, solid line) when compared to conventional array designs.

**The proposal is to adapt the design of the above antenna to a low-cost, planar, UWB antenna array system based on the requirements of the NRL.**

**Feasibility of Technical Objectives:** Low-profile conformal arrays are attracting much attention to the development UWB phased arrays antennas. The proposed design exhibits well-behaved impedance and radiation patterns over a wide bandwidth. Therefore, they are capable of transmitting information over a large bandwidth. However, there is another UWB phased array antenna feature which plays a significant role in their broadband performance. While these type of antennas are costly and difficult to fabricate, the proposed antenna designs are a planar, inherently low-profile structure. A key benefit of the new antenna designs is also their low-cost due to use of low-cost materials and manufacturing process.

**Offeror's R&D Capabilities:** The University of Malta team is being led by Dr. Kristian Zarb Adami, whose main area of research is experimental radio cosmology. The team is capable of end-to-end antenna system design and works with various small enterprises for prototyping purposes. Common activity areas with the NRL include UWB technology; Electromagnetics and Antennas; In situ array calibration; Signal Analysis and Real-time signal processing and equipment. Key publications include:

[1] E. Farhat, K. Adami, Y. Zhang, A. Brown and C. Sammut," Ultra-wideband tightly coupled fractal octagonal phased array antenna.'' In Electromagnetics in Advanced Applications (ICEAA), 2013 International Conference on, Sept 2013,pp. 140-144.

[2] E. Farhat, K. Adami, Y. Zhang, A. Brown, and C. Sammut, J. Abela," Aperture Arrays for radio astronomy,'' in Electromagnetics in Advanced Applications (ICEAA), 2014 International Conference on, Aug. 2014, pp. 185-190.

[3] E. O. Farhat, K. Z. Adami, Y. Zhang,  A. K. Brown, and C. V. Sammut, "Ultra-Wideband Tightly Coupled Phased Array Antenna for Low-Frequency Radio Telescope,'' Progress In Electromagnetics Research Symposium Proceedings, Stockholm, Sweden, pp. 245-249, Aug. 2013.

**Cost Estimate:** The project will fall under budget activity 2 with potential for a follow on project under budget activity 3. The current cost estimate for a project of 1 year duration is a total of $450,000, which can be split into stand-alone subsets of effort as follows: (a) antenna design, $68K, (b) system design, $118K, (c) prototyping, $149K and (d) prototype testing, $115K.

**Feasibility of Proposed Approach:** The trend is to combine many antenna functionalities within a single wideband aperture. Of particular importance are bandwidth, very small size and low-profile which have been successfully combined for a radio astronomy application. The team now wishes to apply this novel design to other wideband applications, as highlighted by the NRL.

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[2] HFSS means High Frequency Structural Simulator by ANSYS. CST means the electromagnetic simulation software created by Computer Simulation Technology Ltd.